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EARLY MAYA ADAPTIVE PATTERNS: MID–LATE HOLOCENE PALEOENVIRONMENTAL EVIDENCE FROM PACIFIC GUATEMALA

Hector Neff, Deborah M. Pearsall, John G. Jones, Bárbara Arroyo,
Shawn K. Collins, and Dorothy E. Freidel

We summarize what is known about Archaic period occupation of southeastern Mesoamerica and Central America as background for presenting new paleoenvironmental evidence of pre-Early Formative human impacts on the landscape of Pacific coastal Guatemala. Our evidence comes from sediment cores in three locations, all of which are in the mangrove-estuary zone of the lower coast. Pollen and phytoliths from the cores document increased burning, decreased forest cover, the appearance of domesticates, and increased disturbance indicators at various times during the Archaic period, the earliest being around 3500 cal B.C. The available evidence demonstrates that shifting horticulture was an early and widespread adaptation to the southeastern Mesoamerican deciduous tropical forest and constituted the base from which later adaptations, including that of early Maya farmers, differentiated. Early Formative adaptive innovations may have been favored by shifts in return rates from various estuarine and terrestrial resources during a dry and variable interval 2000 and 1500 cal B.C.

A continuación se resume la información conocida de la ocupación del período Arcaico en el sureste de Mesoamérica y Centroamérica, como antecedente para la presentación de reciente evidencia paleoambiental del impacto humano en el paisaje de la costa del Pacífico de Guatemala antes del Formativo. Esta evidencia proviene de columnas de sedimentos recuperadas en tres lugares de la zona de manglares y esteros de la costa baja. El polen y los fitolitos encontrados en las columnas documentan un incremento en la quema, decrecimiento de la cobertura del bosque, surgimiento de plantas domesticadas y mayores indicadores de perturbaciones en varios momentos durante el período Arcaico, empezando tan temprano como hacia el 3500 cal. a.C. La evidencia disponible demuestra que la horticultura fue una temprana y extensa adaptación al bosque deciduo tropical del sureste de Mesoamérica y constituye la base de la diferenciación de las adaptaciones más tardías, incluyendo aquellas de los agricultores mayas. Las innovaciones de adaptación del Formativo Temprano pudieron verse favorecidas por los cambios en las tasas de retorno de varios de los recursos terrestres y del estero provocados por condiciones climáticas secas y variables entre los años 2000 y 1500 cal a.C.

Key steps in the evolution of civilization in the Maya area took place between about 2000 and 800 cal B.C. At the beginning of this period, Late Archaic foragers were collecting shellfish and other estuarine products in a few lower-coastal locations and, perhaps, exploiting maize and other terrestrial resources on higher ground (Kennett and Voorhies 1996; Voorhies 2004; Voorhies et al. 1991). By the end of the period, monumental architecture was being constructed at La Blanca (Love 1999, 2002), Izapa (Lowe et al. 1982), El Trapiche (in the Chalchuapa zone [Sharer 1978]), and Yarumela (Dixon et al. 1994), and people in most locations apparently depended heavily on maize agriculture (Blake, Chisholm, Clark, and Mudar 1992; Blake, Chisholm, Clark, Voorhies, and Love 1992). The fundamental shifts in subsistence, the increased tethering of people to specific locations, and the beginning of major investment in architectural

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infrastructure arguably set the stage for the later emergence of Maya civilization.

Early Formative adaptive shifts seem to have involved much of the southeastern Mesoamerican lowlands. Best known is the Pacific Coast, where several projects have sampled the pertinent archaeological record in southern Chiapas (Blake 1991; Blake et al. 1995; Ceja 1985; Clark 1991, 1994; Clark and Gosser 1995; Lowe 1975) and southwestern Guatemala (Coe 1961; Coe and Flannery 1967; Love 2002; Pye 1995; Pye and Demarest 1991; Shook and Hatch 1979). Since 1990, archaeological reconnaissance and test excavations along the lower coast of Guatemala have demonstrated that a nearly unbroken chain of Early Formative sites extends from southwestern Guatemala, where Coe (1961) first identified the Early Formative at La Victoria, southeast across the estuarine zone of central Pacific Guatemala (Arroyo 1994, 1995a, 2000, 2001; Arroyo and Neff 1996; Arroyo et al. 2001; Neff et al. 2000) and onto the lower coast of southeastern Guatemala (Estrada Belli and Kosakowsky 1996; Estrada Belli et al. 1996, 1997, 1998; Kosakowsky and Estrada Belli 1997). By the Locona phase (1600–1400 cal. B.C.), Early Formative settlement reached north to the Gulf Coast side of the Isthmus of Tehuantepec, where the Locona phase has parallels with the Ojochí phase at San Lorenzo (Clark 1991; Coe and Diehl 1980). To the east, Locona-like occupations are present in southwestern El Salvador (Arroyo 1995b; Sharer 1978), at Copan (Joyce and Henderson 2001; Viel 1993), and in the Ulua Valley (Joyce and Henderson 2001). Thus, before 1200 B.C., culturally related populations of Early Formative villagers occupied a large swath of territory encompassing the Pacific lowlands and the trans-isthmian region stretching across western El Salvador and Honduras. These Early Formative populations may have included ancestors of early agricultural migrants into the Maya highlands and lowlands (e.g., Andrews V 1990). Another possibility, not necessarily mutually exclusive of the foregoing, is that Early Formative occupants of the Pacific coast, El Salvador, and Honduras communicated key adaptive innovations to resident lowland and highland Archaic populations to their north (e.g., Cheetham 2005; Clark and Cheetham 2002).

The rapid expansion after 1800 B.C. of Early Formative villagers throughout a broad region of what later became Maya territory begs investigation of the process by which the highly successful adaptation of these early villagers evolved out of and supplanted the preceding Archaic period adaptations. Unfortunately, despite pioneering work by Pohl et al. (1996), which documented the timing and nature of Archaic-period human adaptation in Belize, the empirical basis for such an investigation is meager. For instance, in Pacific Guatemala, arguably within the homeland of the Early Formative adaptive pattern, there are as yet no documented Archaic period archaeological contexts. The present paper addresses the empirical deficiencies from two perspectives. First, we summarize published evidence for pre-Early Formative occupations in Central America and southeastern Mesoamerica. Second, we augment the existing published record by presenting results of our own recent paleoenvironmental research in Pacific Guatemala, which document activities of Archaic-period populations practicing shifting horticulture at least 1,500 years prior to the spread of Early Formative populations along the lower coast. Our understanding of the Late Archaic adaptive pattern also relies on theoretical considerations about tropical-forest dweller decision making in an environment undergoing modification due to human subsistence activities (e.g., Kennett et al. 2006; Piperno 2006; Piperno and Pearsall 1998). Ultimately we argue that the Archaic to Formative transition was a punctuated evolutionary event associated with population fragmentation caused by reduction in available moisture shortly after 2000 cal B.C.

Archaic Period Adaptive Patterns in Southeastern Mesoamerica and Central America

The adaptations of Archaic period populations in southeastern Mesoamerica and Central America are documented by archaeological remains from rockshelters and open-air sites in a variety of environmental contexts between Chiapas and Panama and by core samples from lakes and other wetland environments throughout this region (Figure 1). This evidence suggests that Archaic peoples exploited resources in a variety of environmental settings, that they incorporated maize and other domesticates into their diet, and that their activities had important impacts on the tropical landscape. The following paragraphs summarize the

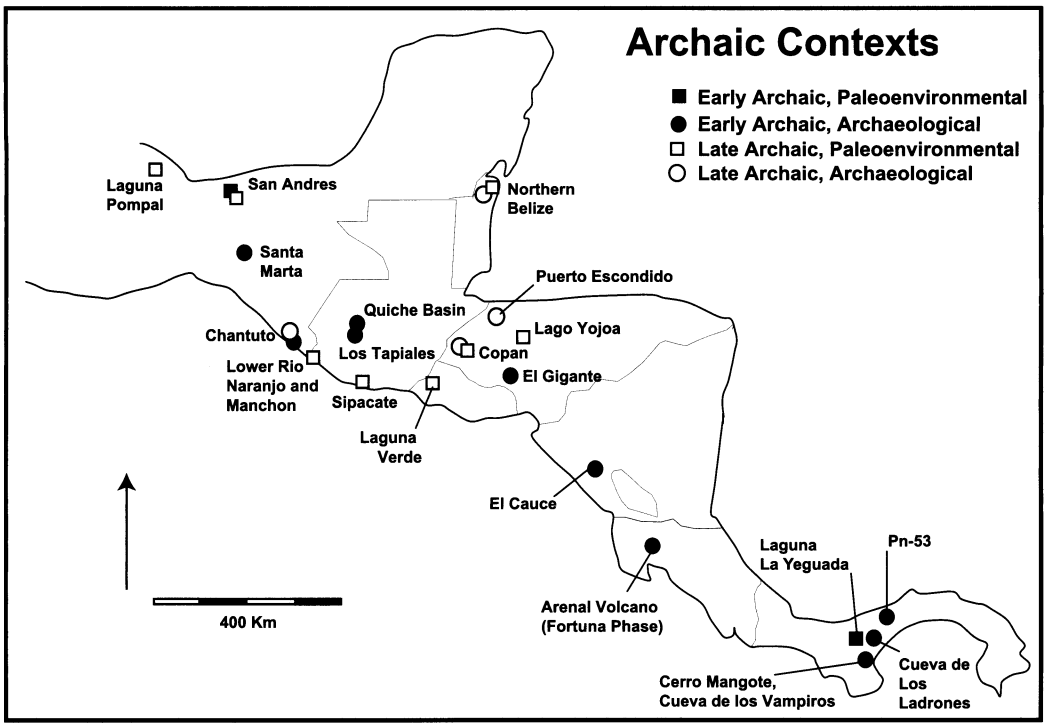

Figure 1. Map of southeastern Mesoamerica and Central America showing Archaic Period archaeological contexts and paleoenvironmental sampling locations discussed in the text.

archaeological and paleoenvironmental evidence for Proto/Early Archaic (9000 – 4000 cal B.C.) and Late Archaic (4000 – 2000 cal B.C.) adaptive patterns.

9000–4000 cal B.C.

Some of the best evidence pertaining to the nature of early human adaptations to the Central American region comes from central Panama, where human impacts on the natural environment began around 11,000 radiocarbon years B.P. in the watershed of Laguna La Yeguada (Cooke 2005; Piperno and Pearsall 1998; Ranere and Cooke 1996). Archaeological remains from various caves in central Pacific Panama investigated by Ranere and Cooke (1996; Cooke 2005) together with paleoenvironmental evidence document intensification of plant use, including the use of likely protodomesticates, by around 8600 radiocarbon years B.P. Piperno et al. (1985) argue that pollen and phytoliths from Cueva de los Ladrones indicate the presence of domesticated maize just above a level dated to 6910 radiocarbon years B.P., and maize appears just above a level dated to 5860 radiocarbon years B.P. in the Laguna La Yeguada core (Piperno et al. 1991). Site density in central Panama also increases dramatically after 7,000 radiocarbon years B.P. (Ranere and Cooke 1996:60–61).

Recent work on the Caribbean side of Panama (Griggs 2005) indicates that wetter, less-productive evergreen tropical forests were also occupied by around 5000 cal B.C. A burned rock midden feature at Pn-53, 23.5 km from the Caribbean coast in the drainage of the Río Indio, yielded two radiocarbon dates on carbonized seeds of economically useful plants (not maize) whose calibrated 1-sigma ranges fall between 4520 and 4845 cal B.C.. Two pottery sherds from the feature hint that ceramic use may have begun on the Panamanian isthmus much earlier than the currently accepted date of around 2900 cal. B.C. More importantly, in conjunction with pollen evidence of early maize from a core in the Gatun Basin (Bartlett et al. 1969), the new archaeological evidence revitalizes the hypothesis that maize-based horticulture enabled penetration of evergreen tropical forests of the Caribbean watershed by shortly after 5000 cal B.C. (Griggs 2005:337).

Early Archaic occupation is also detectable in paleoenvironmental and archaeological records north of Panama. On the Gulf Coast of Mesoamerica, Pope et al. (2001) report a date of 5100 cal B.C. for the initiation of maize cultivation, indicated by the presence of *Zea* pollen outside the natural range of teosinte. *Zea* pollen consistent in size with modern maize appears by 5000 cal B.C. Combined with the early dates for maize pollen and phytoliths in Panama, this evidence supports the hypothesis that maize was dispersing into lowland regions of Mesoamerica and Central America before 5000 cal B.C.

Santa Marta rockshelter in Chiapas (MacNeish and Peterson 1962) and El Gigante rockshelter, in south-central Honduras (Scheffler 2002) provide archaeological evidence that Early Archaic people exploited a diverse range of plant and animal resources. Occupation at El Gigante began before 9000 cal B.C., and the Archaic levels appear to date earlier than 5000 cal B.C. Storage pits may imply extended residence in the cave. Surprisingly, in light of the evidence of maize on the Gulf Coast and in Panama by 5000 cal B.C., maize macrofossils are not found in the Archaic levels of either Santa Marta or El Gigante (MacNeish and Peterson 1962; Scheffler 2002). Pollen, unfortunately, was not preserved at El Gigante, and phytolith studies have not yet been reported. Absence of maize in these interior locations may reflect the fact that the Archaic occupation in both rockshelters predates 4000 cal B.C. Guila Naquitz Cave, Oaxaca, where AMS dates on a maize cob calibrate to around 4300 cal B.C., remains the earliest secure instance of maize in the interior of the continent as well as the earliest directly dated maize macrofossils anywhere (Piperno and Flannery 2001).

Interior contexts other than caves and rockshelters also provide evidence of diverse resource exploitation patterns after the seventh millennium B.C. In the Quiche Basin of highland Guatemala, for instance, Brown (1980) recorded a variety of aceramic sites, which included limited activity sites and larger sites with diverse lithic tool assemblages that had access to a wide range of environmental zones. At another western-highland Guatemalan site, Los Tapiales (Gruhn and Bryan 1977), hearths at a likely game-ambush location produced radiocarbon dates that fall between 4800 and 5500 cal B.C. (the site also has a Paleoindian occupation). On the shore of Lake Managua, Nicaragua, footprints in a surface that dates to around 5700 cal B.C. (Bryan 1973) indicate that lacustrine resources were another focus of inland Archaic-period people. In Costa Rica, evidence of an Archaic presence in the central cordillera comes from the Fortuna Phase, defined by Bradley (1994) and Sheets (1994a, 1994b) on the basis of deposits found underneath volcanic ash layers deposited by Arenal Volcano between about 5000 and 3700 cal B.C. Surface finds of Archaic lithics from Costa Rica and Central Panama are similar to lithic assemblages from five central Panamanian rockshelters occupied between 8,500 and 5000 cal B.C. (Cooke 2005:139).

Complementing the various terrestrial and lacustrine adaptations, an orientation to estuarine and marine resources emerged during the Middle Holocene, perhaps favored by slowing sea-level rise, which permitted the establishment of mangroves and expansion of productive estuary-lagoon systems. In Panama, the shell midden site of Cerro Mangote contains faunal remains documenting systematic exploitation of the coastal mangrove estuaries between 5600 and 3500 cal B.C. (Cooke and Ranere 1999). The estuarine focus is also found within southern Mesoamerica, where it is best represented by the Chantuto shell-midden sites investigated by Voorhies and her collaborators (Kennett and Voorhies 1996; Michaels and Voorhies 1999; Voorhies 2004; Voorhies et al. 2001). At Cerro de las Conchas, occupation began by 5500 cal B.C., when the occupants emphasized procurement of marsh clams from the lagoons at the interior margin of the estuary zone (Voorhies et al. 2000). Faunal remains indicated the subsistence focus shifted over time to include lower-estuary and marine species, apparently in response to encroachment of the ocean during the final phases of postglacial marine transgression.

In summary, Archaic-period people were exploiting a variety of habitats in southern Mesoamerica and Central America before 4000 cal B.C. Along the Gulf Coast and in Panama, forest clearance began before 4000 cal B.C., and a variety of domesticates or proto-domesticates were present. Elsewhere, coastal estuaries, lake shores, highlands, and other interior zones supported human populations. Although the lack of archaeological evidence may reflect preservation bias, it is

worth noting that large areas of lowland seasonal tropical forest, especially the coastal plain of Pacific Chiapas and Guatemala, show no evidence of human foragers prior to 4000 cal B.C.

4000–2000 cal B.C.

Although Archaic-period archaeological contexts postdating 4000 cal B.C. are surprisingly rare, human impacts on the landscape during this period can be detected in sediment records across a wide area stretching from the Gulf Coast of Mexico to western El Salvador and Honduras. These sediment records together with fragmentary Late Archaic archaeological evidence suggest a pattern of extensive land use by horticultural people who exploited terrestrial fauna and wild plants but also modified the tropical forest ecosystem and incorporated domesticates into their subsistence regime.

As discussed above, *Zea* consistent in size with modern *Zea mays* appears as early as 5000 cal B.C. in a pollen record from the San Andres site, on the Gulf Coast of Mexico (Pope et al. 2001). The signal of human activities persists at this location, manioc pollen appearing by around 4600 cal B.C., coincident with maximum land clearance, and sunflower being added to the local botanical assemblage by about 2600 cal B.C. Elsewhere on the Gulf Coast, a core in Laguna Pompal, in the Sierra de Los Tuxtlas, recovered basal sediments dating to around 2800 cal B.C. that contained *Zea mays* and relatively high levels of disturbance indicators (Goman and Byrne 1998), showing that forest clearance and agricultural impacts predate 2800 cal B.C. there.

At the extreme southern end of the Maya area, Laguna Verde, in the Sierra de Apaneca of El Salvador, has yielded a pollen core in which charcoal concentration and weedy taxa increase in levels dated to around 3500 cal B.C. and *Zea* pollen, arguably from *Zea mays*, first appears in a level dated to 2440 cal B.C. (Dull 2004a, 2004b). Nearby, a core from Laguna Cuzcachapa, at the archaeological site of Chalchuapa, shows very high levels of *Zea mays* pollen from the lowest levels, which date to 1760 cal B.C. (Dull 2004a).

Paleoenvironmental and archaeological evidence from western and central Honduras also document shifting horticulture during Late Archaic times. A core from Lago Yojoa yielded maize and abundant grass in levels immediately above a radiocarbon date with a calibrated 1-sigma range from 2931 to 3965 cal B.C. (Rue 1989; Rue et al. 2002). In the Copan Valley, a core in a peat bog, Aguada Petapilla, penetrated sediments containing *Zea mays* that date to 2300 cal B.C. or earlier (Rue et al. 2002). Also in the Copan Valley, archaeological evidence of Late Archaic populations was reported by Longyear (1948), who encountered a preceramic deposit of charcoal, faunal remains, and lithics beneath the Copan acropolis. And finally, at Puerto Escondido, in the Ulua Valley, Joyce and Henderson (2001) report an aceramic deposit of obsidian, bone, and shell that probably pertains to the Late Archaic. The Puerto Escondido basal deposit lies below ceramic-bearing levels with two associated radiocarbon dates, one whose 2-sigma range extends back to 1745 cal B.C. (Joyce and Henderson 2001:Table 1).

The Late Archaic of Belize is documented by both archaeological and paleoenvironmental evidence (Cheetham 2005; Clark and Cheetham 2002; Iceland 1997; Pohl et al.1996; Rosenswig 2004). Constricted unifacially worked macro-flakes made of local chert and apparently used for woodworking and as hoes are the most conspicuous components of the Late Archaic archaeological record in northern Belize (Iceland 1997; Rosenswig 2004). Pohl and her colleagues (1996; Jones 1994) report pollen evidence that maize and manioc were present in the Belizean forest as early as 3400 cal B.C., but the obvious landscape changes associated with agriculture—increased charcoal, decreased tree pollen, and increased open-habitat pollen—occurred after 2400 cal B.C. The archaeological and paleoenvironmental evidence indicate that the Late Archaic people responsible for deforestation in Belize after 2400 cal B.C. were primarily adapted to wetland environments (Pohl et al. 1996; Rosenswig 2004). This aceramic Late Archaic adaptation persisted longer in Belize than elsewhere, pottery and villages not appearing in Belize until around 1000 cal B.C. (Andrews V 1990; Cheetham 2005).

Additional archaeological evidence of Late Archaic adaptive patterns comes from the Chantuto Zone of southern coastal Chiapas, where Voorhies's (1976, 2004) work demonstrates continuity of the earlier pattern of estuarine-resource exploitation known from Cerro de Las Conchas. A noteworthy feature of the Chantuto shell middens

is the low diversity of both faunal remains (extreme dominance of a single species of marsh clam) and artifacts (a few obsidian chips and a few ground stone artifacts). The middens consist of alternating layers of burned and unburned shell, possibly a result of episodic clam bakes (Kennett and Voorhies 1996; Voorhies 2004). The bedding and the undisturbed nature of the deposits, the low diversity of artifacts, and the paucity of evidence of domestic structures indicate that they were special purpose processing sites within a logistically organized collecting economy (Kennett et al. 2006; Voorhies 2004).

Voorhies (2004; Voorhies and Kennett 1995) suggests that the visibility of the Chantuto people's estuarine-resource procurement activities may be largely due to biased preservation, their residential bases on the coastal plain being obscured by high sedimentation rates associated with monsoonal rainfall and periodic mega-floods. The single known interior preceramic site on the Chiapas coast, Vuelta Limón, consists of a scatter of obsidian chips and fire-cracked rock associated with a single radiocarbon date that falls near the end of the Archaic period (Voorhies 2004; Voorhies and Kennett 1995). Indirect evidence for interior residence comes from an analysis of oxygen-18 content of shell from the Chantuto middens (Kennett and Voorhies 1996), which suggests a trend during the Late Archaic toward avoidance of the wetlands during the dry season. Kennett and Voorhies (1996) argue that this trend was driven by scheduling conflicts with dry-land agricultural commitments. Along similar indirect lines, stable-carbon isotope analysis of Late Archaic skeletal remains from one of the shell middens yielded results consistent with a maize-dominated diet (Blake, Chisholm, Clark, Voorhies, and Love 1992), although these results have been questioned (Ambrose and Norr 1994). Finally, phytoliths from one of the shell middens (Tlacuachero) also indicate the presence of Late Archaic maize (Jones and Voorhies 2004). Analysis of sediment cores obtained recently by Kennett, Voorhies, and their collaborators should provide a clearer picture of the terrestrial side of the adaptation of the Late Archaic Chantuto people. In the meantime, the scarcity of *archaeological* evidence for human occupation of the interior coastal plain bears reiteration: while the shell middens are impressive in volume, and there is indirect evidence that the estuarine focus must have been complemented by dry-land activities, the subsistence system as a whole only supported mobile groups whose activities (aside from shellfish collecting) barely rose above the threshold of archaeological visibility.

The combined evidence from paleoenvironmental and archaeological investigations into Late Archaic adaptations in southern Mesoamerica presents something of a paradox. Although Late Archaic archaeological contexts are nonexistent, special-purpose, fragmentary, or ephemeral, the sediment records almost universally show increasing charcoal flux, decreasing arboreal taxa, and increasing disturbance taxa at various times between 4600 cal B.C. (Gulf Coast) and 2400 cal B.C. (Belize). In other words, relatively few people, so few that they are all but archaeologically invisible except in a few locations, appear to have had major, important effects on the mid-Holocene landscape. Where Late Archaic occupations achieve high visibility, such as the Chantuto zone, the remains are consistent with episodic exploitation of locally abundant resources, and the broader picture of Late Archaic subsistence and settlement is barely discernible in the archaeological record. Domesticates, particularly maize, were available to these Late Archaic people (as the pollen evidence shows), but the resource package as a whole only supported extensive human subsistence. That is, despite the evidence of human impacts on the landscape, there is no evidence prior to 1800 B.C. that intensification of horticultural activities yielded productivity gains that supported major increases in carrying capacity or an evolutionary trend toward intensive food production and sedentary residence. Results from Pacific Guatemala, discussed below, amplify these inferences.

Pacific Guatemala

The Pacific coast of Guatemala (Figure 2) is a broad, fertile plain between a chain of active, dormant, and extinct volcanoes and the Pacific Ocean. Rain falls mainly during the summer rainy season and amounts to 2,000 to 3,000 mm annually at the coast and 3,000 to 4,000 mm annually on the piedmont (Vivó Escoto 1965). Short rivers drain the highlands across the coastal plain, in most cases ending in a biotically productive lagoon and man-

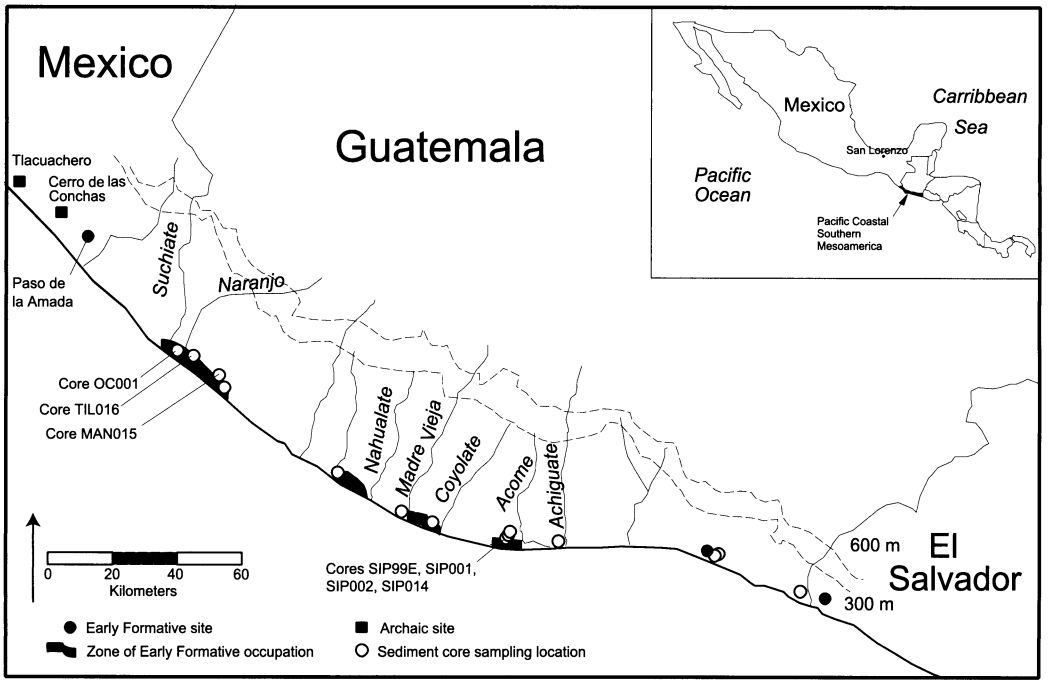

Figure 2. Map of the Pacific coast of southern Chiapas, Mexico and Guatemala showing Archaic Period archaeological sites, zones of Early Formative occupation, and locations of sediment cores. Cores discussed in the text are labeled.

grove estuary zone similar to the Chantuto zone of Chiapas, discussed above. Replenishment of soil nutrients on the coastal plain by air-fall volcanic ash and water-borne sediments contributes to high agricultural productivity that supported dense human populations from Middle Formative through Terminal Classic times.

Pacific Guatemala is part of a lowland corridor that stretches from the Isthmus of Tehuantepec south across Chiapas and Guatemala to western El Salvador. The network of canals and lagoons within the estuary system facilitates east-west movement (Lowe et al. 1982; Navarette 1978). Ease of travel and communication through this corridor may help account for the remarkable uniformity of Early Formative pottery throughout the Pacific lowlands and for the region's later integration into pan-Mesoamerican political entities, such as the Olmec interaction sphere (Blomster et al. 2005) and the Teotihuacan empire (Bove and Medrano 2003).

Although Archaic period shell middens are conspicuous in the Chantuto zone (Figure 2 and see discussion above), as yet not a single Archaic period archaeological site has been located on the Guatemalan Pacific coast, despite extensive exploration both within the mangrove zone (e.g., Arroyo 1994, 1995a, 2001; Arroyo and Neff 1996) and on the coastal plain (Bove 1989; Love 2002). Hypothesizing that biased preservation is largely responsible for the absence of Archaic occupation in Guatemala, we undertook a program to sample the paleoenvironmental record of Pacific Guatemala in order to obtain information about the early human occupants of this region.

Because there are few lakes on the coastal plain of Guatemala, our sampling program focused on the estuarine zone, where we consistently found waterlogged, anoxic sediments with good preservation of organic remains. We used a vibracorer to obtain intact column samples from these sediments, which we sampled for radiocarbon, pollen, phytolith, and chemical analysis.

Like lake sediments, mangrove sediments preserve a record of climate and ground cover conditions that affected adjacent dry-land environments. In the present context, we are primarily interested in the evidence for human impacts on the vegetation, which is preserved best in fossil pollen and phytoliths as well as charcoal. These constituents were deposited by both fluvial and aerial-transport

processes. Elsewhere (Neff, Pearsall, Jones, Arroyo, Collins, and Freidel 2006), we focus on a climate record obtained largely from elemental analysis of one of the cores, MAN015.

Results

We encountered sediments 3,000 or more years old in three locations, Sipacate (cores SIP001, SIP99E, and SIP014), Manchón (core MAN015), and the lower Río Naranjo (cores TIL016 and OC001). All are near the inland edge of the mangroves, and all are located within zones of Early Formative occupation (Figure 2). The Sipacate cores were taken from an area recently cleared of mangroves for salt production, whereas the Manchón and Tilapa cores came from within the existing mangrove forest. Sediments throughout the Manchón and lower Río Naranjo cores were pollen rich, but the upper levels of the Sipacate cores preserved little pollen.

Calibrated radiocarbon dates from the six cores (Tables 1 and 2) are plotted against depth in Figures 3 and 4. All locations show highest sedimentation rates in the lower parts of the core. Possible contributors to this rate differential include (1) more rapid peat buildup earlier in the Holocene, before sea-level stabilized at approximately its current level; (2) a real decrease over time in sedimentation rate; (3) removal of parts of some of the sequences by flood events; and (4) compaction of the upper portion of the cores during the coring process. MAN015 (Figure 4) shows the most regular relationship between age and depth, with only a slight decrease in sedimentation rate after approximately 2000 cal B.C. and very little deviation from least-squares fit regression lines in either the bottom or the top section of the core. This regular peat accumulation can be attributed to the fact that the MAN015 coring location is a very low energy environment that only receives runoff from small streams. The other locations are closer to major rivers and have more variable sedimentation rates as well as apparent discontinuities perhaps caused by major flood events (e.g., the dip in the curve between 290 and 230 cm in TIL016). Despite some variability in the sedimentation rates, it is clear from the regular patterns of increasing age with depth shown in Figures 3 and 4 that our core samples are intact records of the nature of sediments accumulated at the margin of the Guatemalan Pacific coastal plain over the past 3,000–7,000 years.

Interpretation of paleoenvironmental records may be complicated by the difficulty of distinguishing between effects due to climate change and those due to human impacts (e.g., Brenner et al. 2002; Rosenmeier et al. 2002). For instance, if a pollen record shows declining tree pollen, increasing weedy pollen, and increasing charcoal flux, does this represent a drying climate coupled with natural fires or human impacts? With a single pollen record the question remains moot. But with multiple records from a region, the question may be resolved by noting temporal correlation between the records or the lack of such correlation. Climate change is a global process, which would be expected to have similar, correlated effects across a region of similar climate, such as the Pacific coast of Guatemala. Human impacts, in contrast, are local, and while they *may* occur simultaneously or approximately so across a region, thus mimicking climate change, a *lack* of correlation favors the hypothesis that the changes were human induced. This is one basis for our claim that the environmental changes discussed below are the result of Late Archaic human impacts that began to affect coastal Guatemala around 3500 cal B.C.

Sipacate

The Sipacate locality was sampled by four cores placed within a radius of about 500 m in a salt playa approximately 1 km east of an Early Formative mound complex. The coastal plain north of the coring location is a rich agricultural zone with deep, well-drained loam soils that supported high prehistoric population densities, especially during the Middle and Late Classic periods (Bove and Medrano 2003). Between the coring location and the coastline lies approximately 3 km of lagoons, mangrove forests, and an extinct beach ridge abandoned when the current barrier beach formed.

The Sipacate record documents a nearly 3,000 year period between about 3800 cal B.C. and shortly after 1000 cal B.C. SIP001 sampled sediments deposited between approximately 3800 cal B.C. and 1700 cal B.C. (Table 1 and Figure 3; one anomalous radiocarbon date not shown in Figure 3 suggested an age of close to 10,000 years at the core base, but that date is rejected based on the consistency in the other dates from the bottom section

Table 1. Radiocarbon Ages and Calibrated Dates for Sipacate Cores.

Lab ID	Core and Level	Radiocarbon Age Based on 5568-Year Half-Life	One-sigma Range	$\delta^{13}C$	Calibrated Intercepts and One-Sigma Range Based on Stuiver and Reimer (1993), Version 4.3.
AA45771	SIP014-148-149	156	31	-26.00	cal A.D. 1671(1680,1737,**1805**,1934,1947)1949
AA59207	SIP014-210-211	3109	47	-28.42	cal B.C. 1429(**1400**)1317
AA59211	SIP014-249-250	3419	38	-28.31	cal B.C. 1745(1736,**1712**,1693)1664
AAR5772	SIP014-298-299	4575	47	-21.20	cal B.C. 3368(**3356**)3140
AA59208	SIP014-355-356	4689	39	-28.03	cal B.C. 3618(3503,**3428**,3381)3374
AA42658	SIP014-398-399	4757	75	-27.20	cal B.C. 3642(3627,**3583**,3534)3379
AA36822	SIP001-177-178	4935	50	-25.90	cal B.C. 3768 (**3705**) 3655*
AA36823	SIP001-185-186	3500	45	-27.10	cal B.C. 1883 (1876, 1842, **1812**, 1799, 1778) 1743
AA49364	SIP001-205-210	3428	37	-27.60	cal B.C. 1766(1738,**1707**,1695)1686
AA36824	SIP001-239-240	4125	50	-28.30	cal B.C. 2864 (2837, 2818, **2664**, 2647, 2638) 2581
AA49365	SIP001-270-274	4194	49	-25.80	cal B.C. 2882(2875,**2797**,2790)2696
AA36825	SIP001-285-286	4635	60	-24.50	cal B.C. 3505 (3488, **3472**, 3371) 3356
AA49366	SIP001-295-300	4950	56	-26.70	cal B.C. 3784(**3708**)3658
AA49367	SIP001-330-335	5008	52	-28.00	cal B.C. 3935(**3785**)3709
AA36826	SIP001-332-333	8780	490	-27.40	cal B.C. 8533(7937,7932,7915,7901,7870,7861,7828)7334**
AA42021	SIP99E-105-110	4423	64	-25.10	cal B.C. 3309(3082,**3067**,3030)2921*
AA42021	SIP99E-105-110	2034	37	-24.90	cal B.C. 88 (42,**7**,3) cal A.D. 18*
AA42022	SIP99E-110-115	3212	39	-24.80	cal B.C.1520(1494,**1476**,1459)1432
AA42023	SIP99E-115-120	2930	39	-27.30	cal B.C. 1253(1186,**1183**,1128)1047
AA42024	SIP99E-130-135	3423	39	-27.80	cal B.C. 1748(1737,**1710**,1694)1686
AA42025	SIP99E-155-157	3636	40	-27.70	cal B.C. 2110(2014,**1998**,1979)1940

Note: All samples are organic-rich sediments. Intercept value shown in bold are plotted in figure 3. * = Sample indicated by open triangle in figure 3; ** = Sample not plotted in Figure 3.

Table 2: Radiocarbon Ages and Calibrated Dates for Manchón and Lower Río Naranjo Cores.

Lab ID	Core and Level	Radiocarbon Age Based on 5568-Year Half-Life	One-sigma Range	$\delta^{13}C$	Calibrated Intercepts and One-Sigma Range Based on Stuiver and Reimer (1993), Version 4.3.
AA59210	MAN015-269-270	2412	35	-28.56	cal B.C. 536(**410**)404
AA45762	MAN015-374-375	3776	53	-28.40	cal B.C. 2287(2199,**2156**,2154)2073
AAR5763	MAN015-402-403	4011	58	-28.00	cal B.C. 2617(2558,**2537**,2495)2467
AA45764	MAN015-460-462	4370	41	-29.10	cal B.C. 3079(3005,**3002**,2923)2915
AA45765	MAN015-531-532	4882	46	-28.40	cal B.C. 3702(**3654**)3642
AA45766	MAN015-608-609	5472	51	-27.30	cal B.C. 4352(**4336**)4253
AA42657	MAN015-617-618	5872	50	-26.60	cal B.C. 4797(4770,**4753**,4722)4692
AA45767	TIL016-230-232	1232	42	-27.60	cal A.D. 693(**778**)879
AA59209	TIL016-266-267	5520	360	-28.07	cal B.C. 4771(**4349**)3967*
AA45768	TIL016-290-291	3540	51	-25.40	cal B.C. 2026(1882,**1836**,1834)1702
AA45769	TIL016-323-324	3772	44	-28.40	cal B.C. 2281(2198,**2158**,2151)2138
AA45770	TIL016-363-364	4089	58	-28.30	cal B.C. 2858(2620,2609,**2599**,2587,2584)2499
AA42659	TIL016-427-428	4615	46	-11.60	cal B.C. 3497(**3367**)3354
AA36830	OC001-65-66	**15**	35	-29.10	n/a
AA36831	OC001-115-117	1655	40	-25.50	cal A.D. 343 (**407**) 426
AA36832	OC001-152-153	2508	69	-28.50	cal B.C. 793(762,678,**670**,608,599)414
AA36833	OC001-272-274	2880	59	-32.90	cal B.C. 1206(1039,**1030**,1023)941

Note: All samples are organic-rich sediments. Intercept value shown in bold are plotted in Figure 4. * = Sample indicated by open triangle in Figure 4.

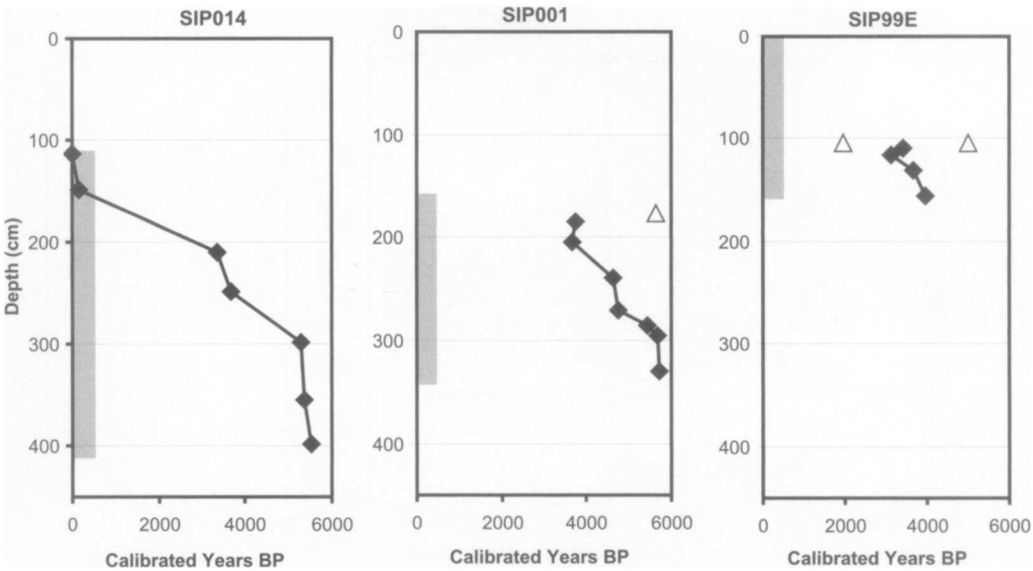

Figure 3. Plots of radiocarbon-date calibration intercept or middle calibration intercept in sediment cores from the Sipacate zone against depth. Shading at left shows portion of each core extracted with vibracorer. Unshaded upper portions represent compaction or portion extracted with auger. SIP99E diagram does not include approximately 1 meter excavated by auger. Open triangles are rejected radiocarbon dates; one date calibrated to 7900 cal B.C. in SIP001 (AA36826 in Table 1) is not shown.

of the core). SIP99E sampled sediments deposited during the Early Formative occupation of the zone, approximately 2000 cal B.C. through sometime after 1100 cal B.C. (Figure 3). Finally, although SIP014 sampled the entire sequence, with a date near the top of cal A.D. 1805 and a near-basal date of 3583 cal B.C. (Figure 3), the post–1000 cal B.C. evidence is equivocal; no pollen is preserved above 170 cm, and the very low apparent rate of sedimentation between about 1400 cal B.C. and cal A.D. 1800 (Figure 3) suggests that one or more major flood events may have eroded parts of the deposit during the past 3,000 years.

The basal sediments sampled by SIP001 and SIP014 indicate that mangroves had become established in the area by shortly after 4000 cal B.C. (Figure 5). The mangrove forest persisted until around 3400 or 3500 cal B.C., during which time tropical forest with palms (*Arecaceae*) and other trees, such as *Coccoloba,* predominated on the dry land adjacent to the mangroves (Figures 5 and 6). In addition, a single pollen grain tentatively identified as *Zea mays* at 370 cm in SIP014 and phytoliths consistent with maize in the lower levels of both cores suggest that maize may have been present in the environment by around 3500 cal B.C. Squash and *Maranta*, other potential economic plants, are represented as well. Although economic species were present, grasses and other disturbance indicators were minor components of the local flora, and charcoal concentrations were comparatively low.

A dramatic change in the environment, recorded in both SIP001 and SIP014, took place shortly after 3500 cal B.C. (Figure 5). Mangroves together with other arboreal taxa declined precipitously as cattails (*Typha*) and sedges (Cyperaceae) increased to high levels. Grasses increased in the SIP014 pollen record, although this is not a pronounced trend and is not clearly detectable in SIP001. Most dramatically, charcoal flux skyrockets in both cores. Based on SIP001, which was sampled more densely and thus offers superior temporal resolution, charcoal levels remained high until sometime between 2800 and 2600 cal B.C. Moreover, multiple peaks and valleys in the charcoal record, particularly in SIP001, suggest that multiple episodes of forest burning took place during the interval 3500–2600 cal B.C.

By around 2000 cal B.C., mangroves had returned to the Sipacate locality and palms were present in the nearby tropical-forest environment. Pollen and phytolith records from SIP001 and

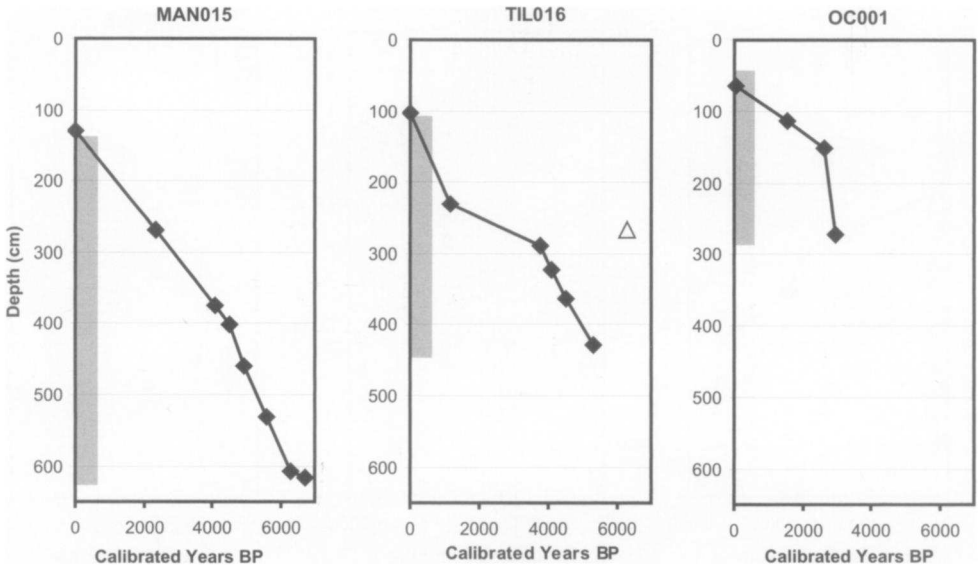

Figure 4. Plots of radiocarbon-date calibration intercept or middle calibration intercept in sediment cores from the Manchón and Lower Río Naranjo zones against depth. Shading at left shows portion of each core extracted with vibracorer. Unshaded upper portions represent compaction. Open triangle is rejected radiocarbon date.

SIP014 (Figures 5 and 6) indicate that this change occurred during the last half of the third millennium B.C. The basal levels of SIP99E (Figure 7) also show mangroves dominating the zone at around 2000 cal B.C. There are some disturbance indictors, such as *Heliconia*, and maize appears in the pollen record and probably in the phytolith record from near the base of SIP99E, between levels dated to 2000 and 1700 cal B.C., but charcoal levels remained low for at least several centuries at the beginning of the second millennium B.C. (Figures 5 and 7). Thus, if there were people in the Sipacate zone around 2000 cal B.C., their numbers were low and they had negligible agricultural impacts on the landscape.

SIP014 and SIP99E both show an abrupt landscape change after 1700 cal B.C., when mangroves declined, sedges returned, grasses of one kind or another increased in both the pollen and phytolith records, and charcoal increased (Figures 5–7). SIP001 does not record this abrupt change because the uppermost level predates it. SIP99E and SIP014 provide somewhat inconsistent evidence regarding the precise timing and nature of the change. Based on SIP99E, the mangrove decline predates 1476 cal B.C. and involves a spike in charcoal as dramatic as that recorded 2,000 years earlier in SIP001 together with an obvious increase in the frequency of *Zea mays* pollen. In SIP014, in contrast, the mangrove decline appears to postdate 1400 cal B.C., the increase in charcoal is not nearly as dramatic as the earlier event, and there is no appreciable increase in *Zea mays* indicators. We believe these discrepancies reflect the greater proximity of SIP99E to the Early Formative mound complex approximately 500 m west of the coring location and the consequent stronger signal of people and their agricultural activities. Radiocarbon dates and ceramics from excavations in the mounds indicate that occupation began between 1600 and 1700 cal B.C. and continued through approximately 1100 cal B.C., a time span that contains the two radiocarbon dates from the charcoal-rich layer in SIP99E.

In sum, sediments sampled in the Sipacate locality appear to document two distinct waves of deforestation associated with early horticulture. The earliest began shortly after 3500 cal B.C. and involved multiple episodes of forest clearance over the next 800 years. The second began after 1700 cal B.C. and coincides with the archaeologically documented presence of Early Formative populations.

Manchón

MAN015 was obtained from the southeastern margin of the Manchón swamp, an extensive

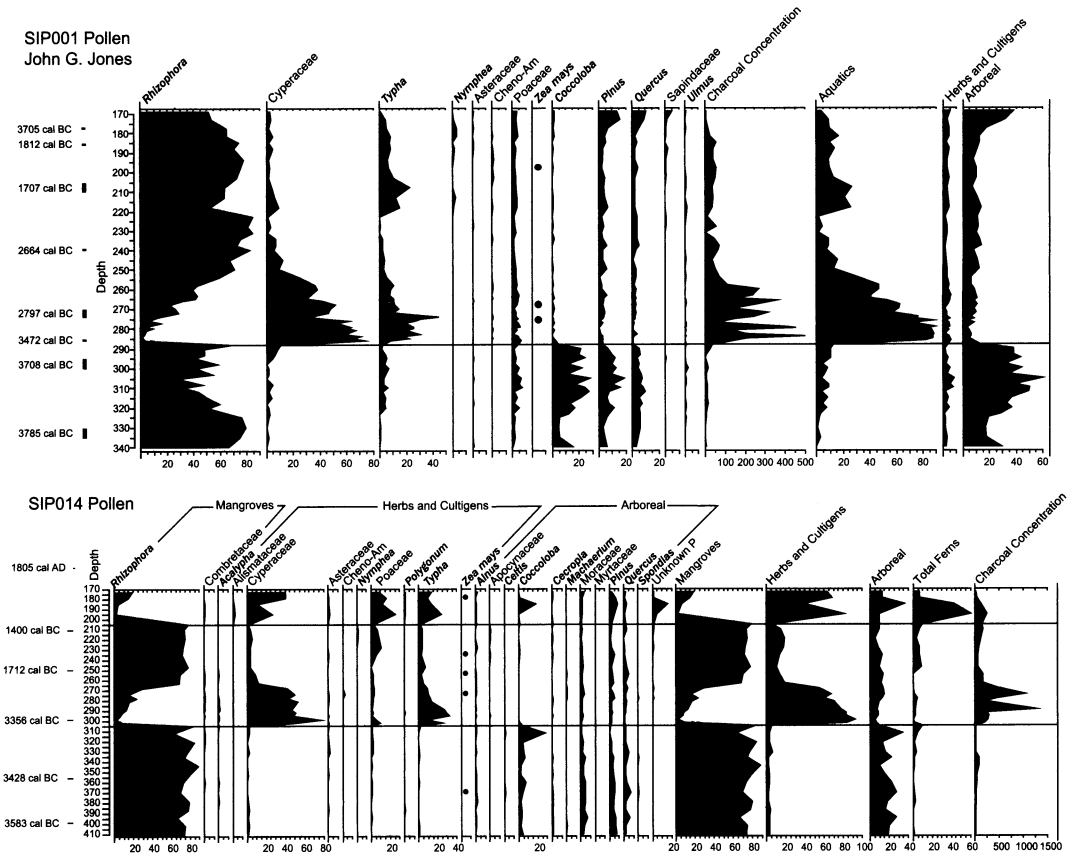

Figure 5. SIP001 and SIP014 pollen data. Horizontal axis indicates percentage of total pollen. For *Zea mays*, dot represents presence. Charcoal concentration indicated as particles per per ml in the 8 to 80-micron size range.

mangrove-estuary system that occupies the southwestern corner of Guatemala, near the Mexican border (Figure 2). There are numerous Early Formative mounds on the shore of the swamp, the closest of which lies only 200 m or so from the coring location. Excavation of one of the mounds (Pye 1995; Pye et al. 1999) and observations during our coring work indicate that occupation began during the Locona phase (probably by around 1500 cal B.C.).

Terrestrial soils adjacent to the southeastern margin of the Manchón swamp are very high in clay content, which probably helps account for the current emphasis on cattle ranching and the absence of farming in the area. Core MAN015 comes from near the inland edge of the mangrove forest, less than 100 m from where the clayey coastal plain soils plunge beneath the swamp. Five km of mangrove forest, canals, and open lagoons lie between MAN015 and the barrier beaches that form the current coastline. This low-energy, anoxic estuarine environment has created a sequence of fine-textured sediments with high organic content, most of it mangrove detritus, accumulated over almost 7,000 years. Pollen preservation is good throughout the core, but there are two intervals of low phytolith deposition (Figure 8) that appear to correlate with carbonate deposition events, which may have been caused by reduced freshwater flux through the estuary and/or higher evaporation rates in an open-lagoon environment (Neff, Pearsall, Jones, Arroyo, Collins, and Freidel 2006).

The basal core sediments have high percentages of mangrove pollen, and, with the exception of an interval centered at around 3000 cal B.C., mangroves dominate the record (Figure 8). The interval at around 3000 cal B.C. coincides with one of the carbonate deposition events mentioned above. Mangroves are reduced at this time and open-habitat species of Chenopodiaceae and *Amaranthus*

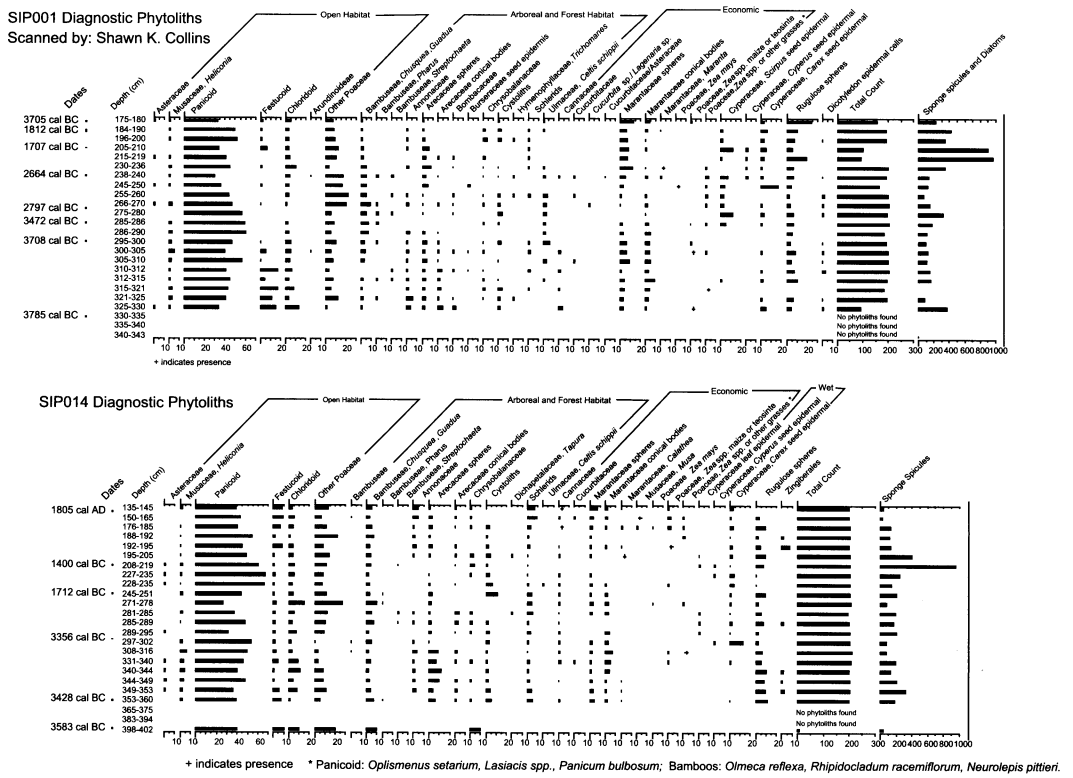

Figure 6. SIP001 and SIP014 phytolith data. Horizontal axis represents percentage of total phytoliths in various taxa.

(Cheno-Am) dominate the record. There is a slight increase in charcoal, but it postdates the surge in Cheno-Am and thus it is difficult to attribute the apparent increasing openness of the landscape to human land clearance. Further, there is no *Zea mays* pollen anywhere in this core, and phytolith indicators of *Zea* (maize or teosinte) are sparsely represented and only in levels above the Cheno-Am spike. Because terrestrial runoff also diminishes around 3000 cal B.C., we interpret these vegetation changes as a response to a drying climate (Neff, Pearsall, Jones, Arroyo, Collins, and Freidel 2006) rather than a signal of human impacts.

A more convincing signal of human presence in the Manchón region is the pronounced charcoal spike between 350 and 300 cm, in levels that date between about 1500 and 1000 cal B.C., based on a regression of depth on calibrated radiocarbon age for the upper part of the core (data shown in Figure 4). That the charcoal reflects human impacts is also suggested by the fact that the other charcoal spike, at around cal A.D. 700 (Figure 8), coincides with the only other archaeologically visible occupation of the eastern Manchón swamp margin, the Classic period. While the Early Formative population of this area is most probably linked to the increased charcoal flux at 1500 cal B.C., there is remarkably little evidence of economic species in the pollen and phytolith records, despite the proximity and density of Early Formative habitation sites. There is a spike in Poaceae phytolith indicators, possibly including *Zea*, in a level dated to around 1900 cal B.C., which may coincide with the earliest human impacts in the region, and a single maize or teosinte phytolith appears in a level dated to around 1050 cal B.C. On the whole, however, the low agricultural potential of the region noted previously seems to have restricted human agricultural activities throughout history, down to the present day.

Lower Río Naranjo

Cores TIL016 and OC001 were obtained, respectively, about 4 km east and 1 km west of the Río

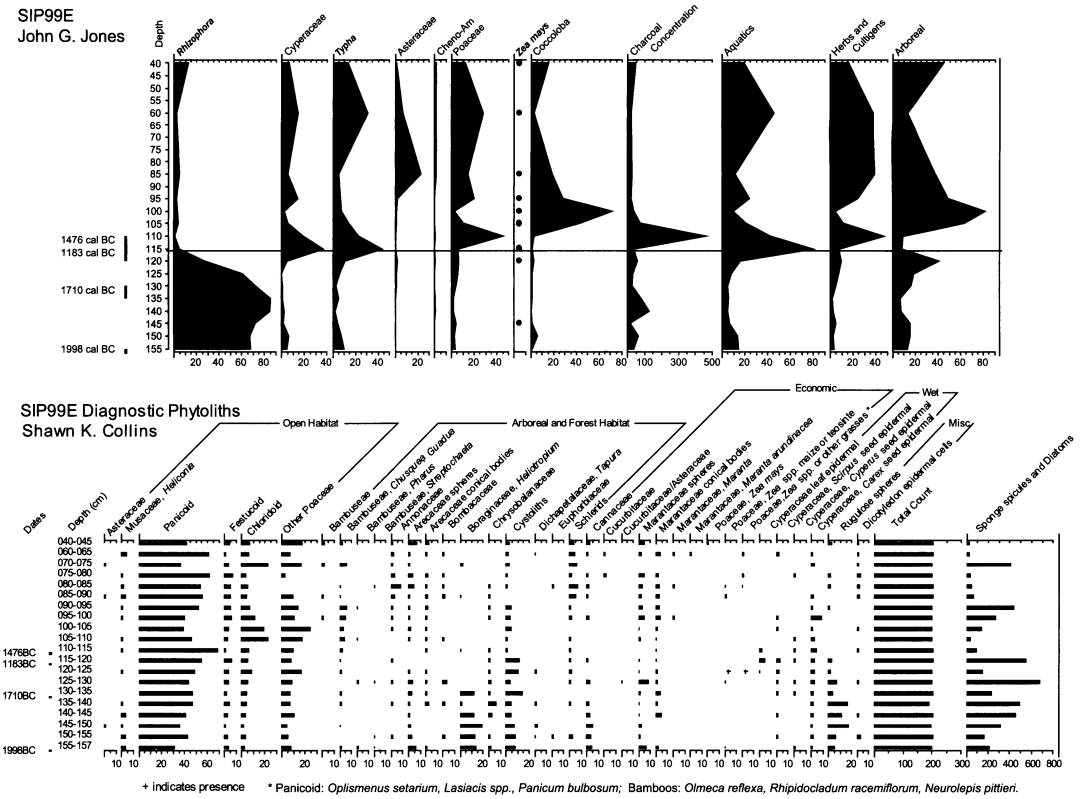

Figure 7. SIP99E pollen (top) and phytolith data. Horizontal axis on the pollen diagram indicates percentage of total pollen. For *Zea mays*, dot represents pollen presence. Charcoal concentration is indicated as particles per ml in the 8 to 80-micron size range. Horizontal axis on the phytolith diagram represents percentage of total phytoliths in various taxa.

Naranjo, a relatively large river that empties into the Pacific Ocean about 6 km from the Mexican border (Figure 2). As at Sipacate, the high agricultural potential of the coastal plain inland from the coring locations supported large populations during several prehistoric periods (Coe and Flannery 1967; Love 2002). Early Formative occupation of the region is well documented at the sites of La Victoria (Coe 1961) and Salinas La Blanca (Coe and Flannery 1967; Shook and Hatch 1978), which lie within about 1 km of the OC001 coring location, and at Cuauhtemoc, on the Mexican side of the border about 12 km northwest of OC001 (Rosenswig 2005). Additional late Early Formative (Cuadros and Jocotal phase) mound sites were identified on dry land adjacent to the mangrove swamp during our own explorations in this region; the TIL016 coring location is about 200 m south of one such site, a large Jocotal phase platform.

TIL016 contains a sediment sequence representing the past 5,400 years, but, unfortunately, a substantial portion of the deposit between 290 cm (with a radiocarbon date of 1836 cal B.C.) and 230 cm (with a date of cal A.D. 778) appears to represent rapid erosion and redeposition, perhaps during a single large flood. This inference is based on the low apparent rate of deposition during this interval (Figure 4), the near absence of charcoal from 240 to 273 cm (Figure 9), the low pollen concentrations in the same interval (not shown), and the absence of sponge spicules in the phytolith samples from 244 through 270 cm (sponge spicules require quiet water to accumulate). There is also an anomalously old radiocarbon date in the middle of this interval, at 266 cm (Figure 4 and 9). Because as much as 2,500 years of the TIL016 record may be missing, we include the OC001 record here (Figure 10), which fills in an important part of the gap encompassing the end of the Early Formative and beginning of the Middle Formative.

The bottom of TIL016, which contains sediments deposited between about 3400 and 2700 cal

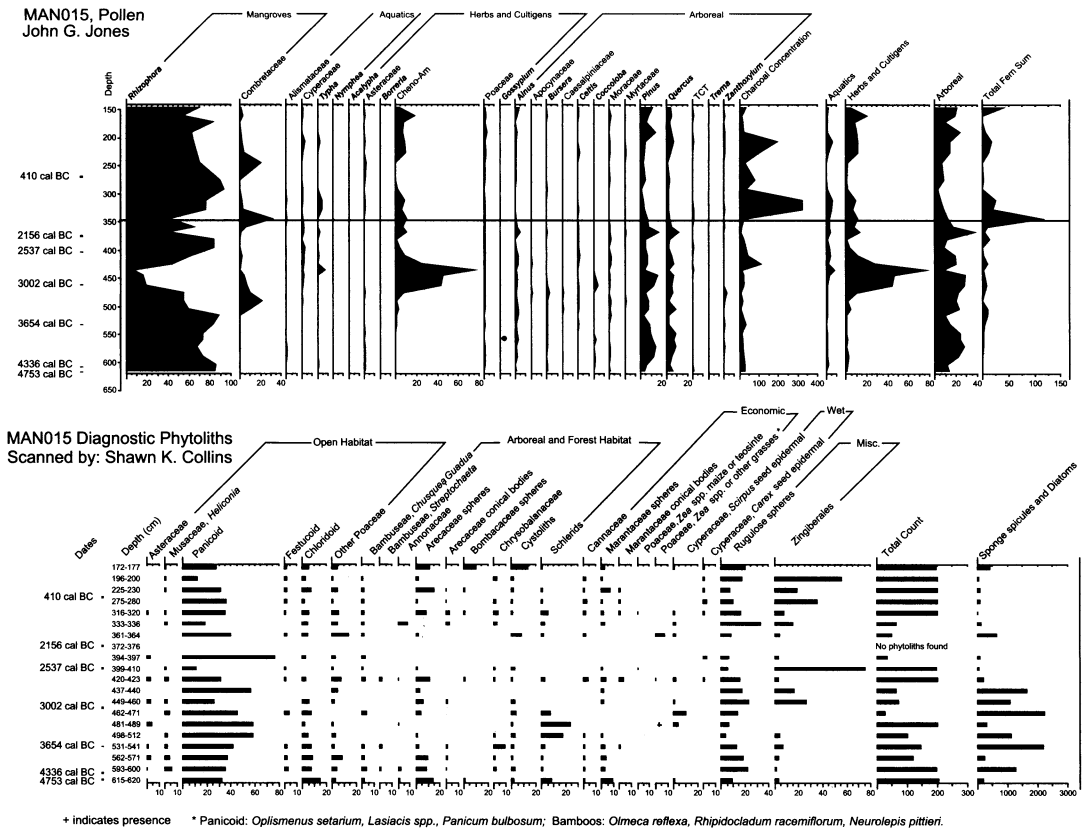

Figure 8. MAN015 pollen (top) and phytolith data. Horizontal axis on the pollen diagram indicates percentage of total pollen. For *Gossypium*, dot represents pollen presence. Charcoal concentration is indicated as particles per ml in the 8 to 80-micron size range. Horizontal axis on the phytolith diagram represents percentage of total phytoliths in various taxa.

B.C., shows dominance of mangroves, low charcoal, low disturbance indicators, and absence of economic indicators, all of which imply an absence of human agricultural impacts (Figure 9). This changes between about 2700 and 2600 cal B.C., when charcoal rises, disturbance species appear in both the pollen (Poaceae and Cheno-Am) and phytolith (*Heliconia*) records, and mangroves begin to decline. Modern *Zea mays* pollen is present by 2600 cal B.C., and *Zea* spp. phytoliths are also present by this time. The microfossil evidence from TIL016 thus identifies the mid-third millennium B.C. as the time when human populations first had detectable impacts on the landscape of the Río Naranjo drainage.

The signal of human impacts persists in TIL016 between the 374 cm and 283 or 291 cm (~2600 through 1800–1500 cal B.C.), but, as mentioned above, the record is truncated sometime during the mid-second millennium B.C. by an erosional event. Charcoal and disturbance indicators (esp. Poaceae pollen and *Heliconia* phytoliths) remain elevated and track each other well in levels deposited between about 2600 and the erosional event, with a pronounced spike in multiple disturbance indicators in a level 1 cm below the 1838 cal B.C. radiocarbon date. In all, TIL016 provides a record of about 800–1100 years of Late Archaic/Initial Early Formative human land-clearance activities in the Río Naranjo drainage.

Although most of the Early Formative is missing from TIL016, OC001 preserves a record that began shortly before 1000 cal B.C. (Figure 10). Deposition was fairly rapid in the bottom of this core (Figure 4). In the lowest sampled level, the few phytoliths present were exclusively from panicoid grasses. *Zea mays* appears in the pollen record by 270 cm, just above the radiocarbon date of 1030 cal B.C., and in the phytolith record by 255 cm. Disturbance indicators (Asteraceae, Cheno-Ams,

and Poaceae) are also present in the lower part of the pollen record, but they dropped out by about 750 cal B.C., perhaps signaling a shift inland by Middle Formative populations.

In summary, the two cores from the lower Río Naranjo region appear to document a single, Late Archaic through Early Formative episode of agricultural land clearance. Core TIL016 demonstrates that human impacts in the Río Naranjo region antedate the Early Formative by as much as 1,000 years. Unlike in Sipacate, there is no interruption in the human signal at the end of the Late Archaic. Unfortunately, the record is truncated in TIL016 after the initial Early Formative, but the lower levels in OC001 indicate that the lower coast was still being cleared for agricultural activities between about 1000 and 750 cal B.C. The archaeological record for this region also provides ample documentation of continuous occupation throughout the Early Formative (Coe 1961; Coe and Flannery 1967; Rosenswig 2005; Shook and Hatch 1978)

Discussion

Archaic Period Horticulture

The claim that seasonal lowland forests of the New World tropics were the settings for early horticulture and plant domestication has substantial empirical support, some of which is summarized in an earlier section of this paper (see also Piperno and Pearsall 1998). The evidence conforms to theoretical expectations, which suggest that energetic advantages of cultivation (of both domesticates and non-domesticates) in a seasonal tropical forest would have selected for its adoption as forests expanded in the New World tropics during the early Holocene (Piperno 2006; Piperno and Pearsall 1998). That is, seasonal tropical forests that have not been impacted by humans are relatively impoverished in high-return resources (e.g., large herd mammals, dense stands of grain plants), so that even a small investment in modifying the natural habitat by clearing and planting yields improved return rates, which would have favored perpetuation and elaboration of such practices.

Consistent with theory and evidence from elsewhere in the New World tropics, the earliest signal of humans in the seasonal tropical forest of Pacific Guatemala indicates a horticultural land-use system. There are no pre-Early Formative archaeological sites of any kind, despite the evidence of hunter-gatherers elsewhere in Mesoamerica and Central America during Paleoindian and Early Archaic times. Instead, the first traces of humans in this region are the marked vegetation changes during the middle Holocene, between 4000 and 1000 cal B.C. The observed changes include declines in arboreal taxa, increases in open-habitat taxa, and increases in charcoal flux. In most cases, economic plants such as *Zea mays* and Cucurbitaceae came into the environment around the time of the other vegetation changes. By their very nature these vegetation changes seem good candidates to have been associated with human horticultural activities. The fact that they occurred at different times in the three investigated Pacific Guatemalan locations provides additional evidence that they are a result of local processes, such as human horticultural activities, not global processes, such as climate change. We conclude, therefore, that our paleoenvironmental records document the arrival of human populations with land-use practices that included clearing, burning, and at least some cultivation of domesticates or proto-domesticates.

Archaic period horticulture was an improvement over hunting and gathering in terms of energy returns in the seasonal tropical forest environment (and indeed may have permitted initial human occupation of many such environments, including Pacific Guatemala), but the initial responses of plants to human cultivation did not create a subsistence system that could support large human populations. One can speculate that, if they were archaeologically visible, Archaic period archaeological sites would be analogous to early horticultural settlements in Panama, Ecuador, Colombia, and northern Peru, which consisted of small hamlets of at most a few nuclear families (Piperno and Pearsall 1998). An analysis by Kennett et al. (2006) identifies the resource characteristics that would have favored low human population growth rates: relatively high production costs of a cultivar such as primitive maize coupled with relatively low harvest efficiency would favor only gradual increases in the abundance of the cultivar, which in turn would limit the growth rate of the population of cultivators.

The moderate efficiency gains of horticulture compared to foraging permitted a gradual spread

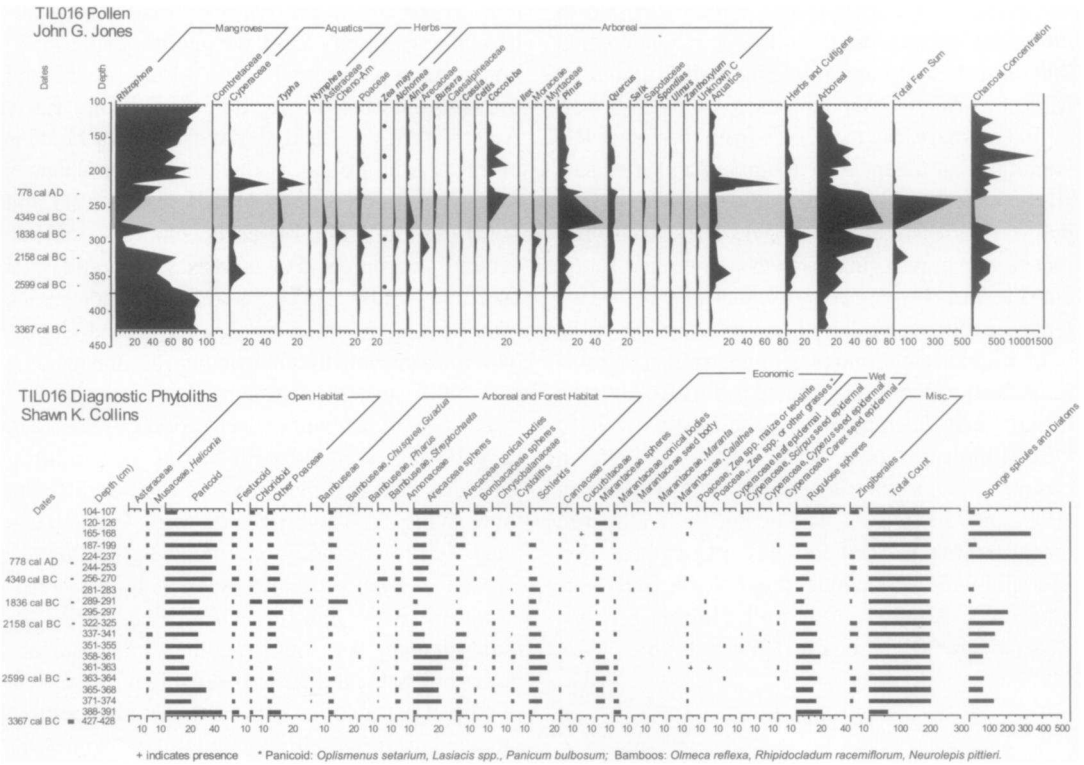

Figure 9. TIL016 pollen (top) and phytolith data. Shaded portion in pollen diagram indicates levels probably associated with a major flood event (note anomalously old radiocarbon date at 266–267 cm). Horizontal axis on the pollen diagram indicates percentage of total pollen. For *Zea mays*, dot represents pollen presence. Charcoal concentration is indicated as particles per ml in the 8 to 80-micron size range. Horizontal axis on the phytolith diagram represents percentage of total phytoliths in various taxa.

of Archaic period horticultural populations across the southeastern Mesoamerican lowlands. As discussed previously, domesticates were present on the Gulf Coast by around 5200 cal B.C., and human land clearance was pronounced in the region by around 4600 cal B.C. (Pope et al. 2001). In Pacific Guatemala, the earliest human impacts we can detect are in the Sipacate zone, at around 3500 cal B.C. At approximately the same time, a similar signal of human land clearance appears in the Sierra de Apaneca of western El Salvador (Dull 2004a) and the Lago Yojoa area of central Honduras (Rue 1989; Rue et al. 2002). Somewhat later, at around 2700 cal B.C., a human signal is detectable in the lower Río Naranjo region, and a little later still, around 2400 cal B.C., forest clearance becomes pronounced in Belize (Pohl et al. 1996) and in the Copan Valley (Rue et al. 2002). Some regions, such as Manchón, do not show obvious human impacts until the middle of the second millennium B.C., roughly coincident with the proliferation of Early Formative archaeological sites. And of course, the interior of the Maya lowlands only shows forest clearance after about 1200 cal B.C. (e.g., Brenner et al. 2002). This evidence suggests that the spread of horticultural populations across the Maya area east of the Isthmus of Tehuantepec may have taken 4,000 years or more (5200 cal B.C. through 1000 cal B.C.).

Not only is there variation in the timing of initial impacts, but, in cases where it can be monitored closely, the signal of Archaic period human impacts in southeastern Mesoamerica waxes and wanes. This is clearest in Sipacate, where the detailed charcoal records of SIP001 and SIP014 indicate multiple short-lived episodes of burning between 3500 and 2700 cal B.C., followed by a drastic reduction in the human signal after 2700 cal B.C. After an

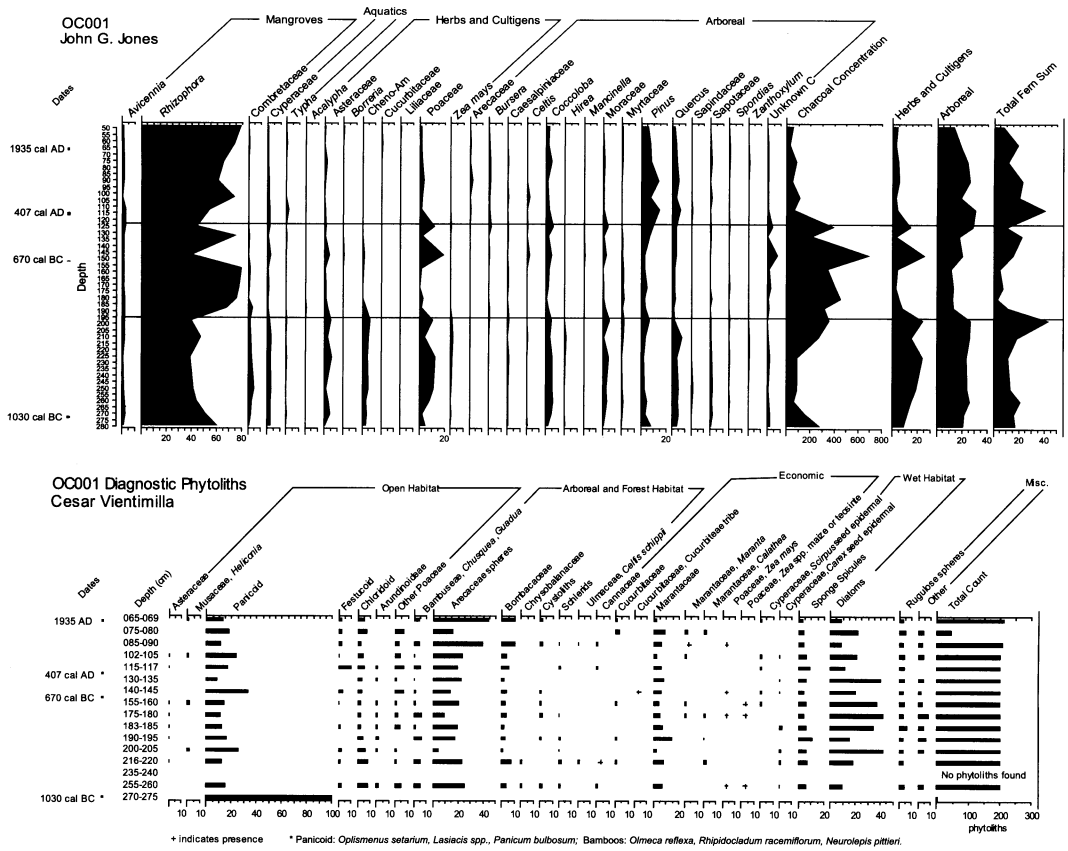

Figure 10. OC001 pollen (top) and phytolith data. Horizontal axis on the pollen diagram indicates percentage of total pollen. Charcoal concentration is indicated as particles per ml in the 8 to 80-micron size range. Horizontal axis on the phytolith diagram represents percentage of total phytoliths in various taxa.

absence of 800–1,000 years, humans returned to the Sipacate area sometime after 2000 cal B.C., when Early Formative archaeological sites appear and the paleoenvironmental record shows renewed human impacts. This paleoenvironmental evidence combined with the dearth of Archaic period archaeological contexts indicates an extensive land-use strategy and low population density in which small groups exploited particular areas until return rates began to decline, prompting a residential move to a fresh forest area. Over a few centuries' time, favorable locations, such as Sipacate, were re-cleared several times. Longer abandonments (e.g., Sipacate after 2700 cal B.C.) and longer continuous occupations (e.g., the Lower Río Naranjo after 2700 cal B.C.) are observable as well.

The available data also permit some inferences about geographic variation in return rates from Archaic-period horticulture. One pertinent observation is that marsh clams offered return rates sufficient to be included in the optimal diet of the Chantuto people of southern Chiapas (e.g., Voorhies 2004). Kennett et al. (2006) estimate return rates for marsh clams at 500–1000 kcal/person/hour, which thus provides a rough lower limit on the average return rates that Pacific coastal Archaic people must have enjoyed from exploiting (higher-ranked) terrestrial resources and invisible estuarine resources (e.g., shrimp). The same logic suggests that average return rates from exploiting terrestrial resources plus invisible estuarine resources on the Guatemalan coast must have been somewhat higher than in the Chantuto zone, as the absence of Archaic shell middens indicates that marsh clams and other shellfish were not part of the optimal diet in Guatemala. Enhanced average return rates from terrestrial plants and animals in Guatemala may have been due to greater soil fer-

tility and consequent enhanced plant resource productivity, greater abundance of large, high-ranked mammals, or other advantages.

The Early Formative Adaptive Shift

The Archaic horticultural adaptation described above features small, dispersed groups and periodic residential moves motivated by declines in average return rates in the local environment. By the end of the third millennium cal B.C., this adaptive pattern combined with population growth had spread horticultural populations across a large part of what later became the Maya area. The next question to address is what accounts for a more-or-less coordinated, rapid shift across most of this area to a new lifestyle, one featuring long-term residence, use of ceramics, and, at least in some locations, incipient monumental architecture (e.g., Blake 1991; Blake and Clark 1999; Clark 1994; Clark and Pye 2000)? Like many evolutionary events that appear to be sudden and pervasive, we suggest that the Early Formative adaptive shift grew out of chance- and selection-driven change within small, isolated populations. One such localized diversification event assembled a new adaptive pattern that proved highly successful under the specific conditions of the second millennium B.C. tropical forests of southeastern Mesoamerica, particularly along the Pacific coast of Guatemala and Chiapas. The archaeological record of many regions presents evidence of similar punctuated adaptive changes (e.g., Bettinger and Baumhoff 1982; Chatters and Prentiss 2005; Prentiss and Chatters 2003).

Climatic changes are among the most likely conditions that would have promoted fragmentation of a dispersed horticultural population into small subpopulations susceptible to both extinction and rapid evolutionary change. Based on recent refinements of the Holocene climate history in the New World tropics (e.g., Haug et al. 2001; Mayewski et al. 2004; Neff, Pearsall, Jones, Arroyo, Collins, and Freidel 2006), the temporal relationship between climate change events and cultural evolutionary events can now be evaluated.

Much of the Archaic period coincides with the Holocene thermal maximum, a ~5,000 year period of relatively warm, moist, and stable conditions throughout the New World tropics that ended around 3000 cal B.C. (e.g., Haug et al. 2001; Mayewski et al. 2004). Forests expanded in the lowland New World tropics during this period, providing a setting in which horticulture was favored over foraging, as discussed above. A high-resolution climate proxy record from the Cariaco Basin (off the north coast of Venezuela) shows stable, moist conditions persisting until approximately 2000 cal B.C., albeit with a gradual drying trend after 3000 cal B.C. Pollen, phytolith, and elemental proxies from the MAN015 core (Neff, Pearsall, Jones, Arroyo, Collins, and Freidel 2006) indicate that conditions in coastal Guatemala were relatively moist prior to 2000 cal B.C., with the exception of a short-lived dry event centered at around 3000 cal B.C. (also recorded in an oxygen-18 climate proxy from a Costa Rican stalagmite [Lachniet et al. 2004]). Warm and moist conditions returned after about 2750 cal B.C. and persisted until about 2000 cal B.C. (Neff, Pearsall, Jones, Arroyo, Collins, and Freidel 2006).

Both the Cariaco Basin record and the MAN015 record indicate that the second millennium cal B.C. was punctuated by a series of extreme dry events in the New World tropics. In the Cariaco Basin, low titanium concentrations mark these episodes as the most extreme dry events between the Younger Dryas, which ended about 9,500 cal B.C., and the recent Little Ice Age (Haug et al. 2001). The first of these dry episodes began immediately after 2000 cal B.C. and peaked between 1850 and 1800 cal B.C. in both the Cariaco and Guatemalan records. Thus, a pervasive, extreme dry event coincides remarkably well with the transition from Archaic to Early Formative human adaptation to the southern Mesoamerican environment.

Attributing the adaptive changes of the Early Formative to climatic deterioration may seem counterintuitive. We suggest that a drying climate played several roles. First, the geographic variation in returns from horticulture discussed in the previous section would have been accentuated by a pervasive reduction in moisture, leading to abandonment of the least favorable areas. This would have promoted fragmentation of the Archaic period horticultural population into relatively isolated subpopulations. Second, declining returns to horticulture in all areas would have favored incorporation of new resources and intensified exploitation of resources already being utilized, in order to sus-

tain productivity. Payoffs from intensification would inevitably have varied because of differences in soil fertility, localized variation in available moisture, and other factors. Variability in the payoffs from intensification in turn would have created between-group fitness differences, with population growth accelerating in the most-favored zones. In short, we hypothesize that climate-driven selection for subsistence changes combined with enhanced potential for group-level evolutionary sorting effects led to the rapid emergence of the Early Formative adaptive pattern shortly after 2000 cal B.C., after which this successful new adaptive pattern rapidly spread throughout a large part of the southeast Mesoamerican lowlands.

Like many cultural evolutionary events (Chatters and Prentiss 2005), the Archaic to Formative transition was so rapid that we are unlikely to observe it archaeologically in much detail. However, existing evidence for the initial Early Formative phases (Barra and Locona) highlight contrasts with the Archaic period that indicate some of the evolutionary novelties that must have arisen during this brief time period.

Barra and Locona phase sites are mound clusters situated along or near extensive estuary-lagoon systems on the lower coast of Pacific Guatemala and Chiapas. Excavations at several such sites have encountered evidence of intensive exploitation of diverse estuarine, marine, and terrestrial fauna (e.g., Arroyo 1994; Blake and Clark 1999; Blake, Chisholm, Clark, Voorhies, and Love 1992; Coe 1961; Rosenswig 2005). The subsistence diversity indicated at lower-coastal Early Formative sites presents a dramatic contrast with the highly specialized reliance on marsh clams at Archaic period sites in the same zone. Although the Chantuto shell middens are presumed to reflect only one facet of a more diversified, terrestrially based subsistence system (e.g., Voorhies 2004), the contrast is equally striking if one only considers resources procured within the estuarine zone; rather than 98+ percent marsh clams, as in the Chantuto middens, estuarine resources represented in the faunal remains from Early Formative sites in Mazatan and elsewhere include a much more diverse array of fish, crustaceans, and shellfish. Artifacts such as net weights and bone fishhooks from Early Formative contexts demonstrate that the new adaptive pattern was enabled in part by technological innovation, which would have improved return rates on species previously excluded from the optimal diet. Conversely, shifts in resource rankings resulting from technological innovation would also have led to exclusion of certain previously exploited resources, such as marsh clams, from the optimal diet.

Midden deposits at Early Formative sites also contain evidence of agricultural production. In the Mazatan region, maize macrobotanical remains are relatively abundant in Locona phase deposits, and their scarcity in Barra phase deposits is attributed to the small size of the Barra phase sample (Blake, Chisholm, Clark, Voorhies, and Love 1992; Blake et al. 1995). Other macrobotanical remains along with grinding stones and ceramic vessels apparently modeled after gourds further attest to the importance of plants to the Early Formative villagers. And, while two of our sediment records from Guatemala show human impacts at one time or another prior to 2000 cal B.C., all three sampled regions show initial (Manchón), renewed (Sipacate), or continuing (lower Río Naranjo) human land clearance during the Early Formative period. Whereas Archaic horticultural activities impacted different regions at different times, Early Formative impacts were pervasive and clearly associated with the proliferation of Early Formative settlements along the lower coast after 1800 cal B.C. Thus, while comparison of Archaic and Early Formative plant use is hampered by the scarcity of Archaic archaeological contexts (other than shell middens in coastal Chiapas), the paleoenvironmental data are compatible with intensified cultivation of crop plants.

The possibility that new plants, particularly new maize varieties, may have been introduced with the Early Formative deserves some consideration. The phytolith record of *Zea* for the Archaic consists mostly of types that are common in modern teosinte species and varieties and rare or absent in modern maize varieties (Pearsall et al. 2003). Near the end of the Archaic at Sipacate, phytoliths that are either specific to *Zea mays* or common in maize appear in the record, and these forms continue to occur in the early Formative sections of the cores. There are no teosinte populations known from the Guatemalan coast, and, because genetic research indicates that maize was domesticated once, in

south-central Mexico (Buckler and Stevens 2005), we interpret the earliest *Zea* phytoliths in our sequences as primitive maize that still retains some teosinte-like silicification patterning, and which was brought into the Pacific coast of Guatemala by Archaic populations. The appearance of phytoliths restricted to, or more common in, maize in the later part of the Archaic record is consistent with the development of a local maize variety or varieties by the resident populations. The *Zea* phytolith records in the Formative sections of the cores show a mixture of primitive and modern features, perhaps suggesting continuity with the Archaic, but this interpretation should be tempered by the fact that *Zea* cob phytolith counts are low. It may be that the question of maize replacement or continuity will remain unanswered until further records are studied, or Archaic sites with macrobotanical remains are discovered.

All in all, however, we are skeptical that more productive maize varieties help to explain the Early Formative adaptive shift. A decline in average return rates caused by reduced available moisture after 2000 B.C., besides promoting incorporation of lower-ranked resources, would also have favored intensified exploitation of existing resources, including maize. If a new, more-productive maize variety had recently arrived on the scene, the combination of declining average returns and increased yield from the new maize variety would have magnified the advantage of maize over alternative resources, thus favoring a rapid shift to heavy reliance on maize. Kennett et al.'s (2006) analysis of cultivator-cultivar interactions also predicts that availability of a more-productive maize variety would favor a rapid, sudden increase in commitment to maize, even in the absence of declining returns from other resources. But as just discussed, Early Formative people, rather than committing to increased reliance on maize, actually expanded the diversity of resources included in their diet, at least judging from the faunal evidence. In addition, while the evidence has been questioned (Ambrose and Norr 1994), bone-isotope data suggest that maize played a *smaller* role in the Early Formative diet than in Late Archaic diets (Blake, Chisholm, Clark, Voorhies, and Love 1992). Even the locations of Early Formative sites—at the edges of the estuarine zone, including regions of low agricultural potential, like Manchón—belies an exclusive or near-exclusive commitment to maize agriculture at the expense of other subsistence pursuits.[1]

The contrasts between Late Archaic and Early Formative adaptive patterns are profound, yet they are incompatible with sudden adoption of a maize-based economy. Instead, the Early Formative adaptive shift seems to have involved a combination of (a) innovations in estuarine-resource extraction technology, (b) consequent broadening of the range of exploited estuarine resources, (c) perhaps similar innovations in horticulture, (d) more permanent residence, and (e) intensified exploitation of terrestrial resources and associated landscape modification within the sustaining area of the residential base. Early Formative people had to work harder and think harder about how to earn a living in a deteriorating environment, and this is the context in which we believe selection shaped a new subsistence system. Over time, this new adaptive pattern entailed new social arrangements as well, as indicated, for example, by very large residential structures and a ballcourt at Paso de la Amada (Blake 1991; Clark and Blake 1994; Hill et al. 1998). This new system ultimately proved successful enough to support population increases that led to rapid proliferation of Early Formative settlements across a wide area of southern Mesoamerica.

Although we believe the increased visibility of Early Formative occupation relative to that of the Archaic period indicates a less-mobile existence, we hesitate to conclude that Early Formative populations were fully sedentary. As described elsewhere (Arroyo and Neff 2001; Neff and Arroyo 2002), Early Formative mounds in coastal Guatemala consist of trash deposits separated by floors, a deposit structure consistent with periodic abandonment and reoccupation. Arguing along parallel lines, Arnold (1999) cites deposit structure as one basis for inferring that Early Formative sites in the Sierra de los Tuxtlas of Gulf coastal Mexico were repeatedly occupied by residentially mobile groups. Arnold notes further that many characteristics of the ubiquitous Early Formative tecomate (neckless ceramic jar) suggest that it was a multipurpose, transportable vessel and that the Early Formative ceramic assemblage as a whole was designed for portability. If Early Formative groups were periodically mobile, exploiting one area intensively until local resources dropped below some threshold and then moving on, such a lifestyle

would have spread adaptive and stylistic traits both via establishment of new villages and via intergroup contact.

Because we have argued that key elements of the Early Formative adaptation arose within a localized region that was relatively hospitable during a time of regional climatic stress, one might wonder where this core zone was located. The abundance of Early Formative sites along the Pacific coast favors the view that Early Formative roots lie somewhere within this region, as has been argued for many years (Coe 1961; Lowe 1967, 1975). For instance, the work of Clark and Blake (1994; Blake and Clark 1999; Blake, Chisholm, Clark, Voorhies, and Love 1992; Blake et al. 1995; Clark 1994; Clark and Gosser 1995) implies that the Mazatan zone of southern Chiapas was close to the Early Formative epicenter. Alternatively, unpublished radiocarbon dates from the bottom of Early Formative contexts in Sipacate excavated by Arroyo are as early as any "acceptable" radiocarbon dates (Blake et al. 1995) from Mazatan, and both the Tecojate zone (Arroyo 1994) and the Sipacate zone have yielded pottery of the Madre Vieja phase (chronologically equivalent to Barra) that shows a developmental sequence leading up to the widely distributed red-rimmed tecomates of the Locona phase (Arroyo 2004).

Although our favored hypothesis, based on early dates and the density of known Early Formative remains, is that this new adaptive pattern arose somewhere on the Pacific coast, we acknowledge that the available evidence partly reflects insufficient investigation of interior regions, particularly in western El Salvador and Honduras. In one place where the effort has been made to sample Early Formative remains, the Ulua Valley of northern Honduras, the earliest ceramic phase (Barahona) starts by 1600 cal B.C. or perhaps even earlier (Joyce and Henderson 2001), which would make its inception virtually indistinguishable in time from the initiation of the Early Formative on the Pacific coast.

If the Early Formative adaptive pattern arose in the Pacific littoral, the diversified subsistence orientation to both estuarine and terrestrial resources may have pre-adapted Early Formative populations for intensive exploitation of lacustrine, riverine, and other wetland environments of the interior. Spread of this basic adaptation and fine-tuning to local environmental circumstances may then have involved both expansion of a growing population out of the Pacific coastal core zone and adoption of key technology and other adaptive traits by resident Archaic populations. Periodic mobility (e.g., Arnold 1999; Neff and Arroyo 2002) would have promoted the spread of both adaptive traits and ceramic styles, and this may partially account for the near-simultaneous appearance of similar Locona-like ceramics along most of the Pacific littoral. Periodic mobility and consequent rapid dissemination of innovations would also help explain the rapid spread of village-farming across the isthmus, to the Ulua River valley of northwestern Honduras (Joyce and Henderson 2001). By perhaps 1000 cal B.C., a ceramic bearing village-farming adaptation was present in the river valleys and around the wetlands of Belize (Cheetham 2005; Clark and Cheetham 2002), and not long afterward, farmers were exploiting wetland resources of the interior Maya lowlands, such as the Mirador Basin, in the heartland of Preclassic and Classic Maya civilization (Hansen et al. 2002).

Conclusion

At the time of the Spanish conquest, speakers of Maya languages dominated Mesoamerica east of the Isthmus of Tehuantepec, including Belize, the Yucatan Peninsula, the Gulf coast of Tabasco and Campeche, and the highlands and Pacific slope of Chiapas and Guatemala. Through archaeology, we know that the ancestors of the conquest-period Maya constructed magnificent cities in the lowlands of northern Guatemala and adjacent regions, invented the only true writing system in the New World, and made sophisticated astronomical and calendrical observations. Maize farming was the engine that drove all of these accomplishments.

Where did the Maya come from? When did they become farmers? When did maize farming start propelling them along a course that would make them dominant over eastern Mesoamerica and allow them to invent writing, build cities, and so on? Questions like these motivated the present study.

It has been clear for some time that important parts of the Maya origin story were written on the Pacific coastal plain of Chiapas and Guatemala (Coe 1961, 1999; Lowe 1975). Early innovations in sedentary living, ceramics, monumental archi-

tecture, sculptural art, and writing can all be traced to this region.[2] Thus, it seemed reasonable to us to look to the Pacific coast to unravel even earlier parts of the Maya story. Disheartened by the scarcity of Archaic period archaeological evidence in Pacific Guatemala, we turned to the paleoenvironmental record as a means to detect a signal of early human activities. We have been rewarded with evidence of human agricultural impacts beginning by 3500 cal B.C., almost 2,000 years earlier than the earliest (Early Formative) archaeological evidence in this region. We believe the evidence now available from Pacific Guatemala and neighboring regions paints a plausible picture of pre-Early Formative adaptation to the southeastern Mesoamerican landscape and of what led up to the emergence of Early Formative villages along the Pacific Coast.

As predicted by Piperno and Pearsall (1998; Piperno 2006), horticultural adaptation emerged early in the deciduous tropical forest of Pacific Guatemala. In fact, modification of the tropical forest landscape for horticulture is the earliest detectable signal of human presence in Pacific Guatemala. In neighboring Chiapas there is an early shellfish-collecting component of the subsistence system, but we expect sediment records currently under study to show early horticultural activities there as well. Although domesticates were available, none responded to cultivation with productivity increases that could underwrite population growth and sedentism. This non-intensive tropical-forest horticultural adaptation became widespread in eastern Mesoamerica and Central America and was the background from which more specialized adaptations, including the early Maya, differentiated after the third millennium cal B.C.

Our specific suggestions about the process by which a relatively sedentary, pottery-using Early Formative adaptive pattern evolved out of Archaic antecedents will certainly be refined or rejected by future research. The association of Early Formative innovations with a dry climate seems relatively clear at the moment, but paleoenvironmental work now in progress in southern Chiapas will provide a further test of this association. Future discovery and investigation of Late Archaic archaeological contexts, especially contexts representing the terrestrial component of subsistence, would clearly provide a major new line of evidence bearing on the issues addressed here. Similarly, additional exploration of the range of variation of Early Formative subsistence and settlement is clearly warranted. Isotopic analysis of Archaic and Early Formative skeletal remains for evidence of diet, analysis of phytoliths and pollen in dental calculus, analysis of residues in Early Formative pottery, and other emergent analytical approaches also have great potential for testing hypotheses about the dietary contributions of different resources. Perhaps most important, we must continue to refine the theoretical framework used to make sense of these empirical observations and to scrutinize the inferential linkages between theory and data.

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Notes

1. The actual ways that Archaic and Early Formative populations used maize is also a matter of some debate. Blake and his colleagues (1992a; Smalley and Blake 2003) have proposed that maize stalk sugar was the early focus of maize exploitation, and that the social lubricating effects of alcohol helped promote the early spread of maize through the Americas. In a related vein, Clark and Blake (1994) have argued that serving maize beer made from fermented stalk sugar was a key strategy used by Early Formative aggrandiz-

ers to gain followers. These suggestions highlight the fact that resources may sometimes have to be evaluated by multiple currencies, making their relative ranking a tricky business (Winterhalder and Kennett 2006).

2. The ceramic sequence on the Gulf Coast parallels that on the Pacific coast during the Locona and Ocos phases (Clark 1991), and by the end of the Early Formative, the Olmec center of San Lorenzo had eclipsed contemporary lowland and highland centers in scale of population aggregation and architectural elaboration (Coe and Diehl 1980; Neff, Blomster, Glascock, Bishop, Blackman, Coe, Cowgill, Cyphers, Diehl, Houston, Joyce, Lipo, and Winter 2006). Thus, while we focus on the Pacific coast, where our own investigations have taken place, we recognize that Gulf Coast groups played key roles in the evolutionary events under consideration here.

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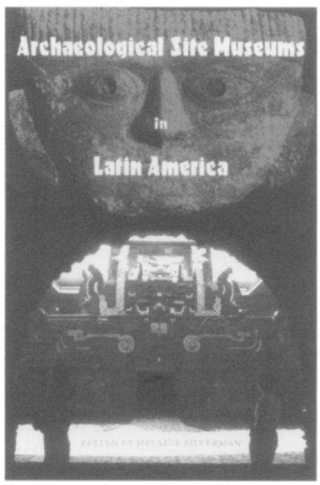

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